“Molecular behavior and structural investigation of Biological Systems through Dielectric Parameters”

Synopsis

Submitted to

स्वामी रामानंद तीर्थ
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SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

For the registration of the topic for
Doctor of Philosophy
in the subject of **PHYSICS**
(Faculty of Science)

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Abstract of proposed work plan/problem:

Molecular behavior and structural investigation of Biological Systems through Dielectric Parameters

1. Introduction:

Biomolecules are any of numerous substances produced by cells and living organisms. These are involved in the maintenance and metabolic processes of living organisms. They consist of Carbon and Hydrogen with Nitrogen, Oxygen, Sulphur and Phosphorus. These are very large molecules of many atoms that are covalently bound together.

The Biological systems include Carbohydrates, Lipids, Proteins, Nucleic acids. Different molecules have different functions. Carbohydrates are energy storage macronutrients. The main function of carbohydrates is to provide energy and food to the nervous system e.g. sugars, starch, glucose, lactose and fibers. Lipids are insoluble in water and include mostly non-polar carbon-carbon or carbon-hydrogen bonds. The function of lipid is to serve as the energy-storing molecule for long–term use. Proteins are the polymers of Amino acids arranged in the form of polypeptide chains. It helps to repair and generate new cells in our body. Nucleic acids are the polymers of Nucleotides. It has the function to store and carry the hereditary information of the cell e.g. DNA, RNA.

The study of dielectric properties of biological systems and their components is a mature field of research that has evolved steadily for almost a century. The technique used is known as dielectric spectroscopy [1]. Dielectric properties are intrinsic properties of biological tissues that can determine the interaction of biological materials with the electromagnetic field. Analysis of dielectric properties of biological materials is of great importance for understanding the structure and physical processes occurring in such biological systems at different levels of complexity. Therefore, electrical measurements on living material are very significant in various areas of biophysics. Dielectric studies can provide useful information about the properties of biological molecules, cells and tissues which have not only biophysical and medical scientific significance but also might have useful clinical applications [2]. In the present work, dielectric spectroscopy is used to know more interesting aspects of the structural and dynamical behavior of biomolecules in their pure liquid state or by changing their concentration, temperature etc.

2.Review of Literature and Development in the subject (Previous work done in the relevant area):

Biomolecules play important role in the Physical, Chemical and Biological processes and are a very important class of organic compounds [3]. Many biological systems such as proteins and enzymes are inactive without water. For a complete knowledge of the function of such systems an understanding of the structure and dynamics of the aqueous environment surrounding the concerned biomolecule is essential [4]. The dielectric properties of biological systems are very remarkable. They typically display extremely high dielectric permittivity at low frequencies. The dielectric constant of all biomolecules shows frequency dispersion and is attributed to ionic polarization [5,12]. Their frequency dependence permits the identification and investigation of several completely different underlying mechanisms and hence dielectric studies of biomaterials have long been important in biophysics.

The dielectric properties of PROTEINS [6,7,8], DNA [9], SUCROSE BORATE [10], FRUCTOSE [11], AMINO ACIDS [12,13,14], GLUCOSE [15] are studied. Dielectric permittivity spectra of amides (DMF and DMA) over entire concentrations with aqueous solution have been measured with different frequency ranges at 25 °C. The permittivity spectra of amide-water mixtures at lower frequencies (20 Hz to 2 MHz) have been measured using Agilent Precision LCR meter E4980A and the same has been measured at higher frequencies using the time domain reflectometry technique in the frequency range of 10 MHz to 30 GHz. Further the Excess permittivity, Kirkwood correlation factor, and Bruggeman factor have been calculated to study the molecular interactions in amides with water molecules. The study has been extended to confirm the molecular interactions among the unlike molecules using the volumetric properties [16]. The frequency-dependent permittivity and dielectric loss of some proteins and nucleic acids, the main classes of biomolecules, and their sub-units have been determined [17].

The Time domain reflectometry (TDR) technique has been used in the frequency range of 10 MHz to 10 GHz to determine the dielectric properties of aqueous sucrose in ethanol. The dielectric parameters, i.e., static dielectric constant and relaxation time were obtained from the complex permittivity spectra [18].The typical bimodal behavior of the dielectric relaxation of water associated with biomolecules can be explained in terms of dynamic exchange between free and bound water species and the strength of the hydrogen bond[19]. Various biomolecules (glucose oxidase, cholesterol oxidase, urease, and uricase) have been immobilized successfully

on the surface of ZnO thin film by electrostatic interaction. SPR reflectance curves for all biomolecules were recorded separately at different wavelengths (407–635 nm). The complex dielectric permittivity was determined by fitting the experimental SPR data with Fresnel's equations. The dielectric permittivity of all biomolecules shows frequency dispersion and is attributed to ionic polarization [20]. Recently the dielectric properties like conductivity (σ), relative permittivity (ε) of (breast, liver, thyroid gland, lung, and prostate tumors.) cancers are discussed. Using the TDR technique, complex permittivity spectra of monosaccharides (D-fructose and D-xylose) and disaccharides (D-maltose monohydrates) were obtained in the frequency range of 10 MHz–50 GHz at various concentrations and temperatures. The static dielectric constant (ε_s), dielectric permittivity at high frequency (ε_∞), relaxation time (τ), and relaxation time distribution parameter (β) where extracted from the complex permittivity spectra using the least-squares fit method. The values of the static dielectric constant were also verified by LCR meter by dielectric measurement in the frequency range of 20Hz to 2 MHz at 25 °C. The relaxation behavior of aqueous solutions of monosaccharides and disaccharides has been illustrated by using the Cole-Davidson model. Activation enthalpy (ΔH), entropy (ΔS), and Kirkwood correlation factors have been determined to study the extent of hydrogen bonding. This data might be useful in the pharmaceutical, food processing industry and solubility prediction method in aqueous solution. [21,22]. Hydrogen bonding phenomenon may lead to(NMR)[23-25] and progressive works on dielectric behavior of hydrogen-bonded liquids using TDR reported [26-30] and in the frequency range, 10 MHz to 50GHz is studied [31].

There are many scientists which are contributed their research in the field of dielectric spectroscopy such as Y. Feldman [32-34], Udo Katze [35,36], S. C. Mehrotra [37,38], R. J. Sengwa [39-41] ,V.A. Rana [42,43], A.C. Kumbharkhane [44-49] etc.

3. Objectives of proposed work:

- Measuring the complex permittivity of interesting biological systems very precisely using the TDR technique.
- Determining the relaxation time, static dielectric permittivity, dielectric loss, activation enthalpy, and high-frequency dielectric permittivity by using suitable mathematical models.
- To measure the refractive indices of associated liquid biological systems.

- ❖ To study the molecular interactions and hydrogen bonding in the associated biological systems.

4. Methodology to be adopted:

Time Domain Reflectometry (TDR) is a powerful technique used for dielectric measurement. The principle of working of this technique is as A fast-rising 250mV voltage pulse with a repetition frequency of a few kHz with the rising time of picoseconds is allowed to transmit through a coaxial line with characteristic impedance 50 Ohm. The co-axial cable semirigid, copper, with a flat end, can be used. Sampling oscilloscope monitors changes in the pulse after reflection from the end of the line. The reflected pulse will be displayed without sample R_1 (t) and with the sample, R_x (t) were digitized with appropriate sampling points in the window. These recorded pulses are added and subtracted and then Fourier transformation has to be performed, resulting in raw spectra. The raw spectra may contain errors and spurious reflections which can be corrected using the calibration method to obtain complex permittivity spectra. The dielectric measurement also can be done at low frequency using the precision LCR meter technique which is in the frequency domain within the frequency range from a few Hz to some MHz. In the LCR technique, the capacitance and parallel resistance of the liquid dielectric test fixture without and with samples must be measured to compensate for a short. The refractive index of the liquid sample will be measured using Abbes' refractometer very precisely.

5. Importance of study/ society applications:

The following scientists are well known in this research field at national and international level:

International Status:

1. N Shiyanshiki, University of Tokyo, Tokyo, Japan
2. S Yagihara, University of Tokyo, Tokyo, Japan
3. S Sudo, Dept. of Physics, Tokyo City Univ. Tamazutsumi, Setagaya, Tokyo, Japan
4. A Katldo, Universita di Lecce, via Monteroni, 73100 Lecce, Italy
5. Udo Kaatze, DrittesPhysikalischesInstitut Georg-August-Universitat Gottingen, Germany.
6. Yuri D Feldman, Department of Applied Physics, Hebrew University of Jerusalem, Jerusalem, Israel.

National Status:

1. S C Mehrotra, Dr. BAMU, Aurangabad, Maharashtra
2. R J Sengwa, JNV University, Jodhpur, Rajasthan
3. A C Kumbharkhane, SRTM University, Nanded, Maharashtra
4. V A Rana, Gujrat University, Ahmedabad, Gujrat

Significance of the study:

As the dielectric spectroscopic technique can be employed non-invasively, this technique is very important and effective for studying biological systems. Dielectric spectroscopy provides quick and accurate frequency dependant permittivity spectra for biological systems such as carbohydrates, amino acids, proteins, DNA, etc. Due to its accuracy, flexibility, large application conditions, and potential for automated measurement, reflectometry has become one of the most attractive methods for monitoring applications. This study is useful in order to explain the various relaxation processes in biomolecules as well as their aqueous solutions. From the analysis of dielectric spectra, one can find the orientation of the molecules, and dipole-dipole interactions of the biomolecules.

6. Work plan/ formulation and structure of study:

- **First Year:** To perform literature survey and to prepare a theoretical background for the related research problem. Choosing an appropriate biological system to be studied.
- **Second Year:** To study the dielectric dispersion of selected biological systems at different frequencies. To evaluate the dielectric properties such as static dielectric permittivity, relaxation time, dielectric permittivity at high frequency and structural information of these systems. To measure the refractive indices and densities of these systems.
- **Third Year:** Dielectric information extracted from data analysis of these systems will be used further for interpretations of molecular behavior and structural characteristics. These interpretations will be published by writing research papers or presenting the work in conference/seminars. Finally, write up thesis and complete the research work.

7. References:

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